

# **Regional Resiliency Assessment Program Dependency Analysis Framework**

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**Risk and Infrastructure Science Center  
Global Security Sciences Division**

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## TABLE OF CONTENTS

Acknowledgment .....	v
Introduction .....	1
1 Defining Dependencies and Interdependencies.....	1
2 Framework for Analyzing Infrastructure Dependencies and Interdependencies .....	2
2.1 Initial Analysis.....	3
2.2 Intermediate Analysis.....	3
2.3 Advanced Analysis.....	7
2.4 Optimal Analysis.....	8
3 Systems Approach to Regional Dependency and Interdependency Analysis .....	9
4 Example Dependency and Interdependency Analyses from Recent RRAP Projects .....	11
4.1 Maine RRAP .....	12
4.2 Florida Fuels RRAP .....	14
4.3 Cajon Pass RRAP .....	15
4.4 Port of Charleston RRAP .....	16
4.5 Ashburn RRAP.....	18
5 Summary and Next Steps.....	20
References .....	21
Appendix A: RRAP Project Examples.....	23

## LIST OF FIGURES

Figure 1 – Dependency and Interdependency between Two Assets.....	1
Figure 2 – Dependency and Interdependency Analysis Framework .....	4
Figure 3 – Top-down and Bottom-up Approaches to Regional Dependency Analysis .....	9
Figure 4 – Possible Effects of the Power Outage Case Study .....	13
Figure 5 – Example of “System of Systems” Modeling and Failure Analysis .....	14
Figure 6 – Repair and Restoration of a Ruptured Natural Gas Pipeline .....	16
Figure 7 – Overview of Upstream Dependencies for Port Terminals .....	17
Figure 8 – Example of Facility Dependency Curve).....	18
Figure 9 – Cluster of Data Centers in Loudoun County.....	18
Figure 10 – Beaumeade Circle Data Center Cluster.....	19

## LIST OF TABLES

Table 1 – Dependency and Interdependency Classes .....	2
Table 2 – Characteristics of Initial Dependencwcy and Interdependency Analysis .....	6
Table 3 – Characteristics of Intermediate Dependency and Interdependency Analysis .....	6
Table 4 – Characteristics of Advanced Dependency and Interdependency Analysis .....	7
Table 5 – Characteristics of Optimal Dependency and Interdependency Analysis .....	8
Table 6 – Comparison of Bottom-up and Top-down Approaches .....	11
Table 7 – Overall Objectives, Stakeholders, and Infrastructure Systems Addressed in Recent RRAPs .....	12

## LIST OF ACRONYMS

CalOES	California Office of Emergency Services
CSA	Cyber Security Advisor
DHS	U.S. Department of Homeland Security
FDEM	Florida Division of Emergency Management
FDLE	Florida Department of Law Enforcement
GIS	Geographic Information System
IDT	Infrastructure Data Taxonomy
MDOT	Maine Department of Transportation
MGS	Maine Geological Survey
NIPP	National Infrastructure Protection Plan
NPPD	National Protection and Programs Directorate
PSA	Protective Security Advisor
PSCD	Protective Security Coordination Division
RRAP	Regional Resiliency Assessment Program
SCADA	Supervisory Control and Data Acquisition
SCPA	South Carolina Ports Authority
SLED	South Carolina State Law Enforcement Division
VDEM	Virginia Department of Emergency Management

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The authors also want to thank their Argonne colleagues who applied the infrastructure dependencies and interdependencies assessment framework in several Regional Resiliency Assessment Program (RRAP) projects. These applications allowed to refine and validate the proposed framework and to provide examples to illustrate this report.

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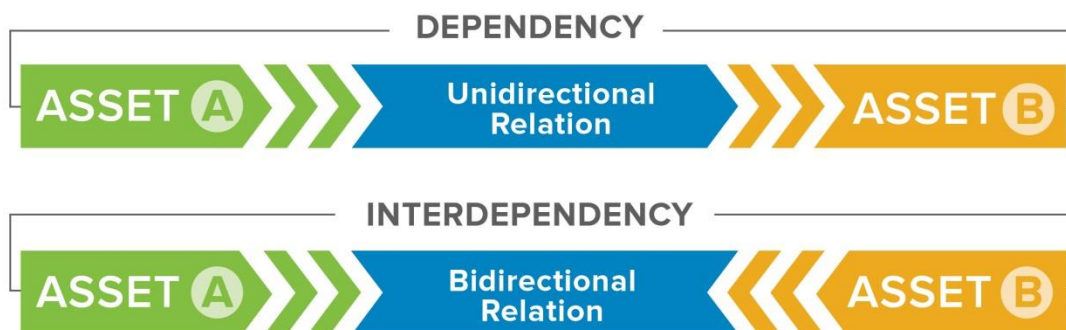
## INTRODUCTION

The purpose of this report is to develop a common understanding and consistent analytic approach for evaluating critical infrastructure dependencies and interdependencies that will inform the programs of the U.S. Department of Homeland Security (DHS) Protective Security Coordination Division (PSCD). The framework outlined here prioritizes a need to tie together top-down and bottom-up analyses<sup>1</sup> to produce a comprehensive “system of systems” view of dependencies and interdependencies that integrates the best available data. Examples of dependency and interdependency analyses from recent Regional Resiliency Assessment Program (RRAP) projects are included to illustrate practical applications of these concepts in support of infrastructure resilience.

### 1 DEFINING DEPENDENCIES AND INTERDEPENDENCIES

A dependency is a unidirectional relationship between two assets where the operations of one asset affect the operations of the other. For example, a water treatment plant depends upon communications services that support the supervisory control and data acquisition (SCADA) systems required to control plant operations.

An interdependency is a bidirectional relationship between two assets where the operations of both assets affect each other. For example, the water treatment plant requires communications for its SCADA system, and, in turn, provides water used by the communications system to cool its equipment. An interdependency is effectively a combination of two dependencies—therefore, understanding an interdependency requires analysis of the one-way dependencies that comprise it. Figure 1 illustrates the definitions of dependency and interdependency.







**Figure 1 – Dependency and Interdependency between Two Assets (Source: Petit *et al.* 2015)**

To analyze infrastructure dependencies and interdependencies, it is helpful to characterize them based on four distinct classes: physical, cyber, geographic, and logical (Table 1).

<sup>1</sup> The National Infrastructure Protection Plan (NIPP) directs the National Protection and Programs Directorate (NPPD) to approach risk management from both a top-down and bottom-up perspective (DHS 2016).

**Table 1 – Dependency and Interdependency Classes (Source: Rinaldi, Peerenboom, and Kelly 2001)**

Class	Description
<b>Physical</b> 	Operations depend on material output(s) of other infrastructure through a functional and structural linkage between the inputs and outputs of two assets. In other words, a commodity produced by one infrastructure is needed as an input by another infrastructure for its operation.
<b>Cyber</b> 	Operations depend on information and data transmitted through the information infrastructure via electronic or informational links. Outputs from the information infrastructure serve as inputs to other infrastructure, with the relevant commodity being information.
<b>Geographic</b> 	Operations depend on the local environmental, where an event can trigger changes in the state of operations in multiple infrastructure assets or systems. A geographic dependency occurs when elements of infrastructure assets are in close spatial proximity (e.g., a joint utility right-of-way).
<b>Logical</b> 	Operations depend on the state of other infrastructure via connections other than physical, cyber, or geographical. Logical dependency is attributable to human decisions and actions and is not the result of physical or cyber processes.

The required data inputs, relevant qualitative and quantitative analytical techniques, and resulting products from dependency and interdependency analyses differ across these four classes. Other dimensions of dependencies and interdependencies that influence the scope and complexity of analysis include:

- Operating environment for critical infrastructure, including broader business, policy, legal, security, safety, and political considerations;
- Coupling and response behavior(s) for critical infrastructure following a disruption;
- Type(s) of failure affecting critical infrastructure;
- Infrastructure characteristics that influence the effects of a disruption; and
- State of operations for critical infrastructure, including normal day-to-day operations, degraded operation, etc.

## 2 FRAMEWORK FOR ANALYZING INFRASTRUCTURE DEPENDENCIES AND INTERDEPENDENCIES

Assessing infrastructure dependencies and interdependencies to improve regional resilience requires a scalable approach that can be tailored based on decision support needs, stakeholder requirements, and relevant critical infrastructure. Performing dependency and interdependency analyses is not a one-size-fits-all activity. Stakeholder goals, available data, time, budget, and analytical sophistication all combine to influence the scope and complexity of potential dependency analysis. Thus, the overarching concept of this framework is to establish a flexible approach that covers a broad spectrum of options, starting with relatively simple and tightly scoped efforts and culminating in more complex, integrated evaluations.

The fundamental steps of dependency and interdependency analysis can be distilled into a framework that aligns a four-step continuum of maturity with relevant data inputs, analytical processes, and end-products. The continuum starts with initial baseline efforts and progresses to an optimal, more holistic approach. Each step in the continuum varies in terms of data required, the type of analysis conducted, and the resulting products. Together, the four steps define a roadmap that can help stakeholders understand and plan for required inputs and desired outputs. Figure 2 summarizes the overall framework, and the sections that follow explore the four steps—initial analysis, intermediate analysis, advanced analysis, and optimal analysis—in greater depth.

### 2.1 Initial Analysis

*Initial Analysis* consists primarily of researching open source information and involves a limited analysis of infrastructure dependencies and interdependencies. This type of analysis offers a general understanding of the functions of a critical infrastructure asset; however, it does not support an understanding of all dimensions of dependencies nor the visualization of cascading and escalating failures. Table 2 presents an overview of the data, analysis, and products characterizing the *Initial Estimate* phase.

### 2.2 Intermediate Analysis

In *Intermediate Analysis*, partners use an evolving set of data collection tools and models that allow for a more detailed analysis of critical infrastructure dependencies and interdependencies. For example, Idaho National Laboratory is piloting a dependency survey tool for use by Protective Security Advisors (PSAs) that uses open source research and service provider interviews in a bottom-up approach to collecting dependency data.<sup>2</sup> Similarly, Argonne National Laboratory (Argonne) is developing an infrastructure impact analysis tool that takes a top-down approach to integrating and automating the interactions of existing system modeling tools for anticipating cascading and escalating failures (Clifford 2015).

Data collection and analyses are starting to address physical, cyber, and geographic dependencies and to initiate the anticipation and visualization of first-order cascading failures. However, most of the existing tools and models (e.g., *EPfast* and *NGfast*)<sup>3</sup> operate in silos and have little interaction with complementary tools and models. Table 3 presents an overview of the data, analysis, and products characterizing the *Intermediate Analysis* step.

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<sup>2</sup> PSAs and Cyber Security Advisors (CSAs) are the core of NPPD's bottom-up approach and serve as the focal point of support to individual critical infrastructure owners and operators (DHS 2016).

<sup>3</sup> *EPfast* is an electric power outage area estimation tool for simulating the behavior of large power systems following power disruptions caused by the loss of power system components. The model explores the possibility of uncontrolled islanding caused by cascading failures and estimates the extent (geographic size) and depth (amount of load shed) of the power outage. *NGfast* uses progressive, forward pipeline ownership identification and flow quantification processes to track lost flow volumes caused by a pipeline break or curtailment in natural gas supply. Impacts are measured in terms of extent of gas volume disrupted, States affected, utilities affected, number and type of customers affected, and amount of natural-gas-based capacity affected.

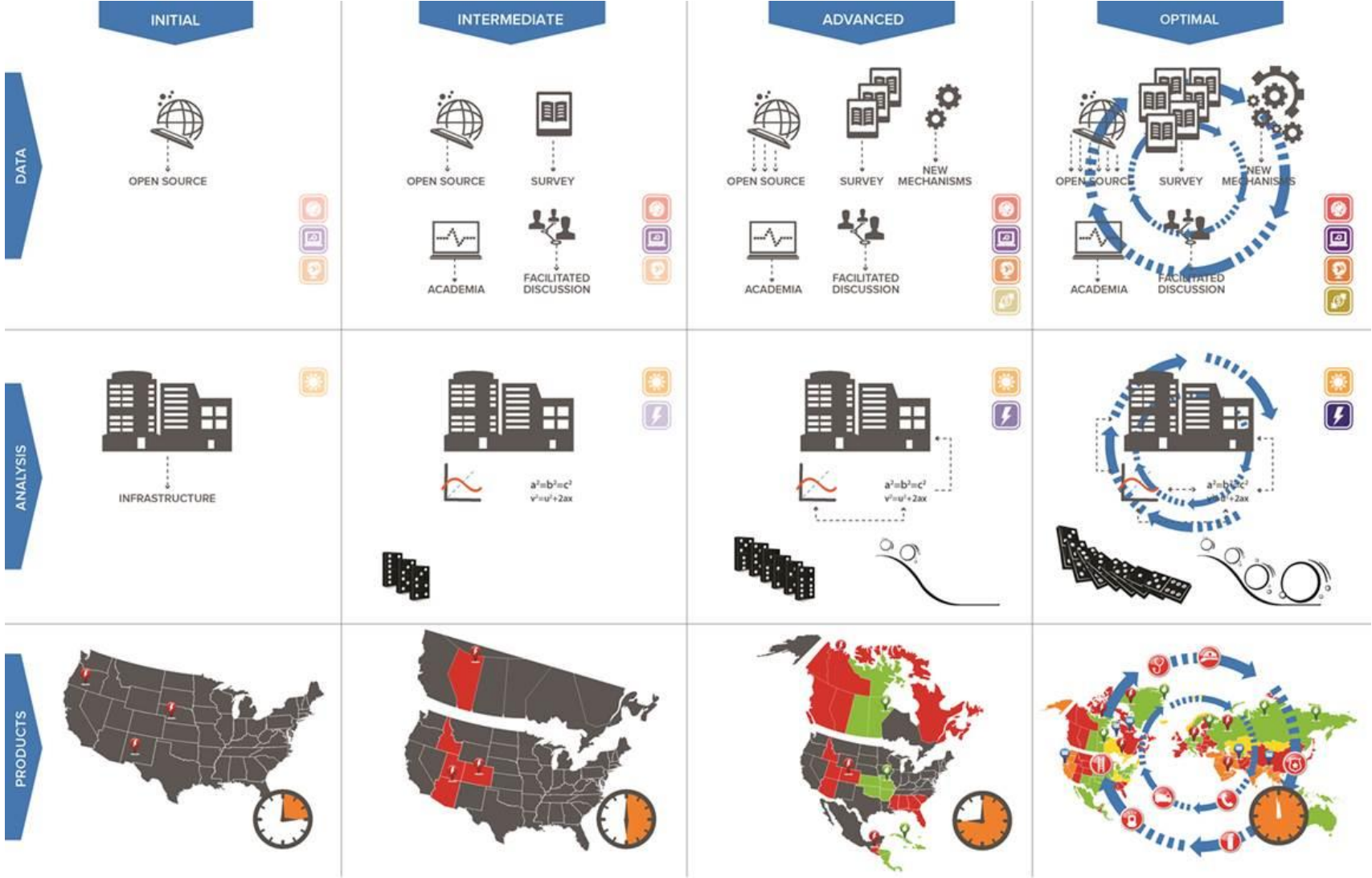


Figure 2 – Dependency and Interdependency Analysis Framework (Source: Petit *et al.* 2015)

## Figure 2 Legend

### DATA Row



Physical Dependencies



Cyber Dependencies



Geographic Dependencies



Logical Dependencies

*The icon's color intensity indicates the degree of analysis from initial (light color) through optimal (strong color).*

*Arrows indicate the increase in data sources from using solely open source information at the initial stage through integrating multiple data sources at the optimal stage.*

### ANALYSIS Row



Normal Operations



Degraded Operations

*The icon's color intensity indicates the degree of analysis from initial (light color) through optimal (strong color).*

*Arrows indicate the increase in models' integrations from identification of critical infrastructure at the initial stage through a total integration of modeling capabilities at the optimal stage.*



Cascading failures (domino effect)



Escalating Failures (snowball effect)






*The augmentation of the number of dominoes and snowballs indicates the increase in the complexity of analysis conducted from considering only first-order dependencies at the initial stage through considering several orders of dependencies at the optimal stage.*

### PRODUCTS Row




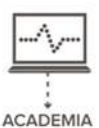








*The different maps indicate the evolution of regional assessment from a general visualization of infrastructure location at the initial stage through an integrated visualization of cascading and escalating failures for all critical infrastructure sectors at the optimal stage.*

*The clock indicates consideration of the timescale characterizing cascading and escalating failures.*

**Table 2 – Characteristics of Initial Dependency and Interdependency Analysis**

Data	Analysis	Products
<ul style="list-style-type: none"> <li>Does not differentiate among physical, cyber, and geographic dependencies</li> <li>Uses primarily open source information</li> </ul>	<ul style="list-style-type: none"> <li>Involves limited analysis</li> <li>Focuses primarily on normal operations</li> <li>Does not address cascading and escalating failures</li> </ul>	<ul style="list-style-type: none"> <li>Provides a general visualization of infrastructure location</li> <li>Reflects a limited understanding of dependencies within a defined geographic area</li> </ul>
 	 	

**Table 3 – Characteristics of Intermediate Dependency and Interdependency Analysis**


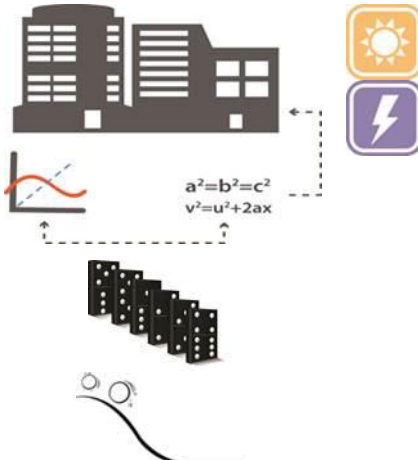

Data	Analysis	Products
<ul style="list-style-type: none"> <li>Addresses physical, cyber, and geographic dependencies, with the main focus remaining on physical dependencies</li> <li>Includes several data sources (e.g., open source information, proprietary and protected databases, surveys, and facilitated discussions with stakeholders)</li> </ul>	<ul style="list-style-type: none"> <li>Uses top-down, system-level models (e.g., <i>EPfast</i>, <i>NGfast</i>) and bottom-up approaches (e.g., interviews, facility assessments) without formal integration of approaches</li> <li>Focuses primarily on normal operations but begins to consider stressed and disrupted operations</li> <li>Involves initial analysis of cascading failures</li> </ul>	<ul style="list-style-type: none"> <li>Provides a refined visualization of system-level dependency links and degradation propagation</li> <li>Reflects a better understanding of first-order cascading failures with some notion of system-level temporal aspects</li> <li>Reflects use of operational tools for characterizing interaction between infrastructure and its environment</li> </ul>
    	     	



## 2.3 Advanced Analysis

*Advanced Analysis* considers all dimensions of critical infrastructure dependencies and interdependencies, including operating environment, coupling and response behaviors, types of failure, infrastructure characteristics, and state of operations (Petit *et al.* 2015). This step requires the creation of new data collection mechanisms and the integration of existing independent assessment approaches. Through this more advanced analysis, partners are able to transition from initial analysis centered on individual facilities to broader systems-level evaluations of infrastructure dependencies and interdependencies. For example, Argonne is conducting an internal research and development project to integrate the *EPfast* and *NGfast* models, which will model electric power and natural gas system interdependencies and simulate cascading failures across multiple states (Portante *et al.* 2016). The multi-system-level, *EPfast-NGfast* modeling and failure analysis is an example of an emerging top-down approach that can combine with new bottom-up approaches, such as the Dependency Survey Tool, to improve regional dependency and interdependency analysis. Table 4 presents an overview of the data, analysis, and products characterizing *Advanced Analysis*.


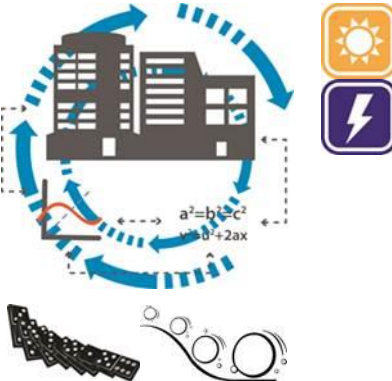

**Table 4 – Characteristics of Advanced Dependency and Interdependency Analysis**

Data	Analysis	Products
<ul style="list-style-type: none"> <li>Considers all classes of dependencies (e.g., added detail on physical and cyber dependencies, with a start on integration/analysis of logical dependencies)</li> <li>Captures new characteristics of dependency dimensions (e.g., operating environment, type of failures)</li> <li>Incorporates new data collection mechanisms</li> </ul>	<ul style="list-style-type: none"> <li>Combines top-down and bottom-up approaches</li> <li>Initiates integration of system-level and facility-level models and assessments</li> <li>Addresses conditions during normal steady-state conditions and degraded operations</li> <li>Refines analysis of cascading failures and initiates analysis of escalating failures</li> </ul>	<ul style="list-style-type: none"> <li>Provides a refined cascading and escalating visualization, including second-order and third-order cascading failures</li> <li>Incorporates temporal and spatial visualization</li> </ul>
 <p>Diagram illustrating data collection mechanisms: Open Source, Survey, New Mechanisms, Academia, and Facilitated Discussion.</p>	 <p>Diagram illustrating analysis: A building icon, a graph with a red curve, a bar chart, and a wavy line. Mathematical formulas are shown: <math>a^2=b^2=c^2</math> and <math>v^2=u^2+2ax</math>.</p>	 <p>Diagram illustrating products: A map of North America showing cascading failures with red and green regions, and a clock icon.</p>

## 2.4 Optimal Analysis

*Optimal Analysis* produces a comprehensive understanding of all dependency and interdependency dimensions. Through these activities, decision-makers can anticipate and characterize, in real time, how all dependency and interdependency dimensions influence the protection and resilience of critical infrastructure systems. This effort requires a collaborative environment that promotes information sharing and multidisciplinary analyses and must expand the overall analysis beyond consideration of critical infrastructure only (e.g., it should consider environmental, social, and economic characteristics of a region). A combined bottom-up and top-down approach can capture global interactions among these subsystems to better understand the resilience of a region. Table 5 presents an overview of the data, analysis, and products characterizing *Optimal Analysis*.

**Table 5 – Characteristics of Optimal Dependency and Interdependency Analysis**

Data	Analysis	Products
<ul style="list-style-type: none"> <li>Considers all dependency categories (upstream, internal, and downstream), classes (physical, cyber, geographic, and logical), and dimensions (operating environment, coupling and response behaviors, types of failure, infrastructure characteristics, and state of operations)</li> <li>Includes integrated data sources</li> </ul>	<ul style="list-style-type: none"> <li>Integrates all dependency dimensions (operating environment, coupling and response behavior, type of failure, infrastructure characteristics, and state of operations)</li> <li>Combines interactive top-down and bottom-up approaches</li> <li>Refines cascading and escalating failures analysis</li> </ul>	<ul style="list-style-type: none"> <li>Provides an integrated visualization of cascading and escalating failures for all critical infrastructure sectors</li> <li>Incorporates improved temporal and spatial considerations supporting anticipation and adaptation processes</li> </ul>
		

### 3 SYSTEMS APPROACH TO REGIONAL DEPENDENCY AND INTERDEPENDENCY ANALYSIS

Infrastructure dependency and interdependency analysis can be analytically complicated, time consuming, and costly, which, in turn, can limit the ability of stakeholders to understand and use this information to make risk-informed decisions that enhance resilience. To manage these complexities, the infrastructure community should use a process that helps partners prioritize resilience assessment efforts through adopting a “systems approach” to performing regional dependency and interdependency analysis.

This approach is based on the assumption that a critical asset or facility can be considered as part of a broader system of infrastructure. Higher-level constructs (e.g., a community or a region) include multiple systems. As such, a community or a region operates as a “system of systems.” Viewed within this framework, high-level systems analysis—using proven and scientifically sound tools—can help identify the most critical lower-level systems. This information can, in turn, help determine where to conduct more detailed site assessments on only the most critical asset-level components (Carlson *et al.* 2012).

A “system of systems” approach can help establish the appropriate scope of a dependency analysis, as well as the specific assets and/or subsystems for which resilience-related information should be collected (Carlson *et al.* 2012). Using this approach, analysis would consider the high-level context (e.g., a geographic region or an industry sector) and the associated states of these systems, ultimately represented by the most critical assets that will inform the scope and focus of a resilience assessment, including the most critical assets from which to collect dependency data.

Executing this “systems of systems” approach requires using hard and soft system methodologies and combining top-down and bottom-up data collection and analysis methods to fully consider regional infrastructure dependencies and interdependencies (Figure 3).

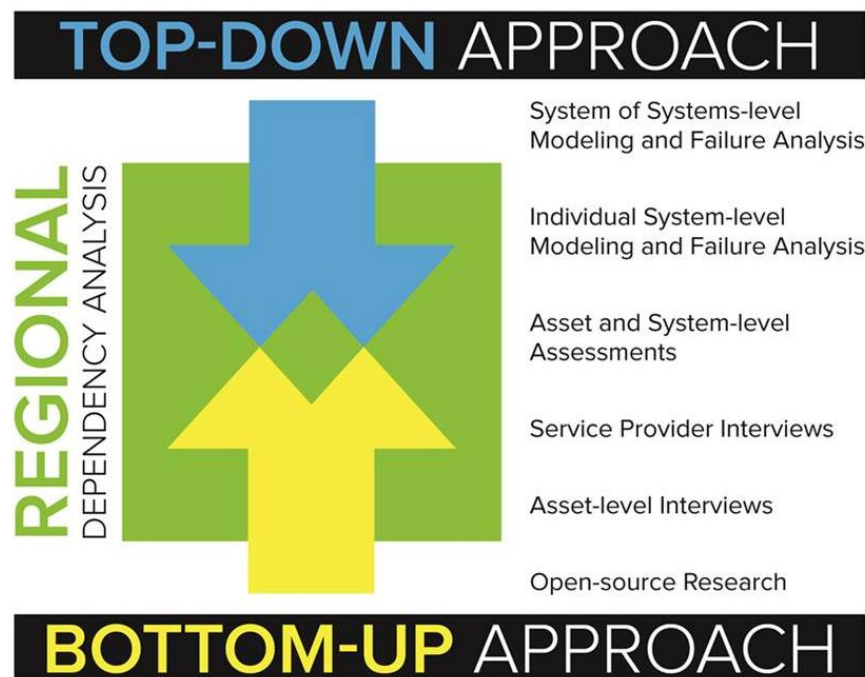


Figure 3 – Top-down and Bottom-up Approaches to Regional Dependency Analysis

Anticipation of cascading and escalating failures requires analyzing risk and resilience capabilities across organizational boundaries (Hokstad, Utne, and Vatn 2012). It is therefore necessary to conduct assessments and cooperate both vertically, that is, within a given sector, and horizontally, or across sectors (Hokstad, Utne, and Vatn 2012).

This approach can be carried out by combining hard and soft system methodologies:

- The *soft system methodology* was designed for analyzing complex system problems and defining ways to “improve the systems and solve the problems identified” (Checkland 1981). This methodology is traditionally used to address human activity systems that cannot be quantified easily (Wastell 2012). The classic soft systems methodology has seven stages and captures different perspectives, including stakeholders’ needs and requirements (Williams 2005).
- *Hard system methodologies* assume that every system can be disaggregated into a number of subsystems and are traditionally used in engineering and operations research. Hard system methodologies traditionally use simulation methods and techniques to represent an abstraction of the system and provide solutions for organizational and managerial problems (Schwaninger 2009).

Top-down and bottom-up approaches are used in several engineering fields, including reliability, safety, system, and resilience engineering (Leveson 2003; Crespi, Galstyan, and Lerman 2005). Top-down approaches involve analyzing a system (or multiple systems) in its entirety and then focusing on its component parts (Crespi, Galstyan, and Lerman 2005). Bottom-up approaches consist of analyzing the component parts of a system individually and then building on this analysis to describe the system as a whole (Crespi, Galstyan, and Lerman 2005). Taking a closer look at two of these engineering fields, reliability engineering generally uses a bottom-up approach to evaluate the effect of component failures on system function, whereas safety engineering generally requires a top-down approach that evaluates how hazardous states can occur at the system level, leading to failures of individual components (Leveson 2003). These failure and hazard analysis techniques are applicable to analysis of all types of systems and subsystems or to an integrated set of systems (Ericson 2015) and can be used for a number of purposes, including:

- Aiding in system design to withstand failure,
- Assisting in operational planning, and
- Providing inputs to risk management (FAA 2000).

Given the dynamic and uncertain nature of threats, there is a critical need for an integrated approach to optimize resilience and protection of critical infrastructure. A top-down approach provides simultaneous analysis of an entire system, enabling decision-makers to define resilience measures for implementation at the system level. A bottom-up approach is more appropriate to determine resilience procedures at the facility level (Gopalakrishnan and Peeta 2010). Combining top-down and bottom-up approaches is a comprehensive method that can be used to support decision-making based on accepted engineering principles (Linkov *et al.* 2014; Hollnagel 2014; Leveson 2011).

Dependencies and interdependencies exist at individual levels (e.g., assets are interconnected with other assets) and between levels (e.g., assets are interconnected with systems, systems with other systems, and so on).<sup>4</sup> Table 6 presents attributes of bottom-up and top-down approaches to critical infrastructure dependencies and interdependencies assessments.

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<sup>4</sup> DHS created the Infrastructure Data Taxonomy (IDT) to facilitate a common understanding of infrastructure terminology within the critical infrastructure protection community. The IDT organizes critical infrastructure in different levels (i.e., sector, subsector, segment, subsegment, and asset) where each component within a level is

**Table 6 – Comparison of Bottom-up and Top-down Approaches**

Bottom-Up Approach	Top-Down Approach
Decentralized	Centralized
Targets data collection at asset level	Targets data collection at system level
Based on actual operations and conditions	Often based on models and large datasets
Identifies facility-level interdependencies	Identifies system-level interdependencies
Moves from the specific to the global	Moves from the global to the specific

#### 4 EXAMPLE DEPENDENCY AND INTERDEPENDENCY ANALYSES FROM RECENT RRAP PROJECTS

The goal of the RRAP is to generate greater understanding and action among public and private sector partners to improve the resilience of a region’s critical infrastructure. Key objectives of RRAP projects include:

- Resolving infrastructure security and resilience knowledge gaps;
- Informing risk management decisions;
- Identifying resilience-building opportunities and strategies; and
- Improving critical partnerships among stakeholders.

Critical infrastructure dependencies and interdependencies are important focus areas for many RRAP projects. Through these collaborative projects, DHS helps stakeholders develop detailed knowledge about critical operational and spatial relationships among important infrastructure systems. The analysis conducted through RRAP projects yields practical outputs for stakeholders, including maps and diagrams that describe important relationships across regional infrastructure; detailed examinations of specific dependencies among assets and systems; and evaluations of the strengths of dependencies and operational alternatives. Together, stakeholders can use these outputs to drive specific actions that improve resilience over a multiyear period, including by expanding knowledge about regional infrastructure and key failure points; improving facility risk management and regional response and recovery planning; and expanding the universe of partners collaborating on infrastructure resilience initiatives.

RRAP projects have explored infrastructure dependencies and interdependencies through a combination of top-down and bottom-up approaches. RRAP activities have included providing broader contextual analyses to understand the likelihood of specific threats and hazards and potential infrastructure failure considerations, as well as tailored interdependency analyses using system-level modeling and asset-based assessments to define potential cascading failures. Table 7 presents the objectives, main stakeholders, and relevant infrastructure systems considered as part of five recent RRAP projects. (Appendix A provides more detailed information on the models used to support this analysis; a description of the dependency analysis process; and data inputs used in the Maine, Florida Fuels, and Ashburn RRAP projects, among others.) The sections that follow provide specific examples of results from these projects that illustrate approaches for analyzing infrastructure dependencies and interdependencies, including a blending of top-down and bottom-up approaches.

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defined by a distinct description. For example, a wastewater lift/pump station X (facility X) is categorized in the Water Sector, Wastewater Facility Sub-Sector, Wastewater Collection System Segment, and Lift/Pump Station Sub-Segment. Furthermore, facility X requires that operational and technical elements (assets) be functional.

**Table 7 – Overall Objectives, Stakeholders, and Infrastructure Systems Addressed in Recent RRAPs**

RRAP Project	Objective	Main Stakeholders	Infrastructure Systems
Maine	Examine coastal lifeline sectors in the context of impacts attributable to climate change and develop products to inform adaptation planning.	Maine Department of Transportation (MDOT), Maine Geological Survey (MGS), and City of Portland	Electric Power, Petroleum, Transportation, Water and Wastewater, Communications
Florida Fuels	Analyze Florida’s transportation system and the critical infrastructure assets it supports that are integral to the delivery of petroleum fuels. Analyze the resilience of port operations and the SCADA systems that support petroleum fuels deliveries.	Florida Division of Emergency Management (FDEM) and Florida Department of Law Enforcement (FDLE)	Petroleum, Transportation, Electric Power, Water and Wastewater, Communications
Cajon Pass	Examine the surface transportation artery via the San Bernardino mountains to Las Vegas and eastward.	California Office of Emergency Services (CalOES)	Transportation, Electric Power, Water and Wastewater, Communications
Ashburn	Provide actionable analysis on the dependencies and interdependencies of lifeline infrastructure supporting the operations of the Ashburn-area data centers.	Virginia Department of Emergency Management (VDEM) and Virginia Homeland Security Advisor	Information Technology, Communications, Electric Power, Water
Charleston	Provide State and local stakeholders with actionable analysis regarding emergency and business continuity planning gaps, critical infrastructure dependencies and interdependencies, and risk mitigation measures to strengthen the region’s transportation sector resilience.	South Carolina Ports Authority (SCPA) and South Carolina State Law Enforcement Division (SLED)	Transportation, Electric Power, Water and Wastewater, Communications

#### 4.1 Maine RRAP

The State of Maine is experiencing shifts in atmospheric and oceanographic conditions that put it at the precipice of abrupt climate change. The Maine RRAP focuses on the local and regional consequences of climate disruptions and their impacts on critical infrastructure in the Casco Bay Region, the most developed and populous region in Maine. As part of this process, the project team conducted a detailed hazard analysis—which involved developing climate projections for the Casco Bay Region based on global climate models, which are dynamically downscaled using a regional climate model. The team then used those results to prioritize and inform related dependency analyses on specific infrastructure systems. For example, the team performed an assessment of the vulnerability of key substations to characterize the resilience of the regional electrical power system to potential future flooding and storm impacts under climate change. This substation case study considered historical and projected changes in average and extreme precipitation, sea-level rise, and storm surge that were then used to define two disruption scenarios.



The failure analysis—predominantly a top-down analysis approach—defined how the disruption scenarios would affect the built environment and lead to the failure of critical infrastructure assets. For the Maine RRAP, the failure analysis used proprietary data sources for locating the infrastructure constituting the electric grid, and fragility curves for defining how electric power infrastructure would be affected by the natural hazard scenarios.

Considering the two scenarios defined during the hazard analysis, the RRAP team projected that six substations would be affected by flooding resulting from a combination of sea-level rise and heavy precipitation. Static mapping products can illustrate high-consequence failure points and potential cascading failures derived from hazard and infrastructure models; however, interactive tools that allow a user to explore the impact(s) of a hazard on the built environment dynamically are often the most impactful means of communicating the outputs of these complex analyses. Figure 4 shows possible effects of the power outage resulting from the RRAP case study analysis.

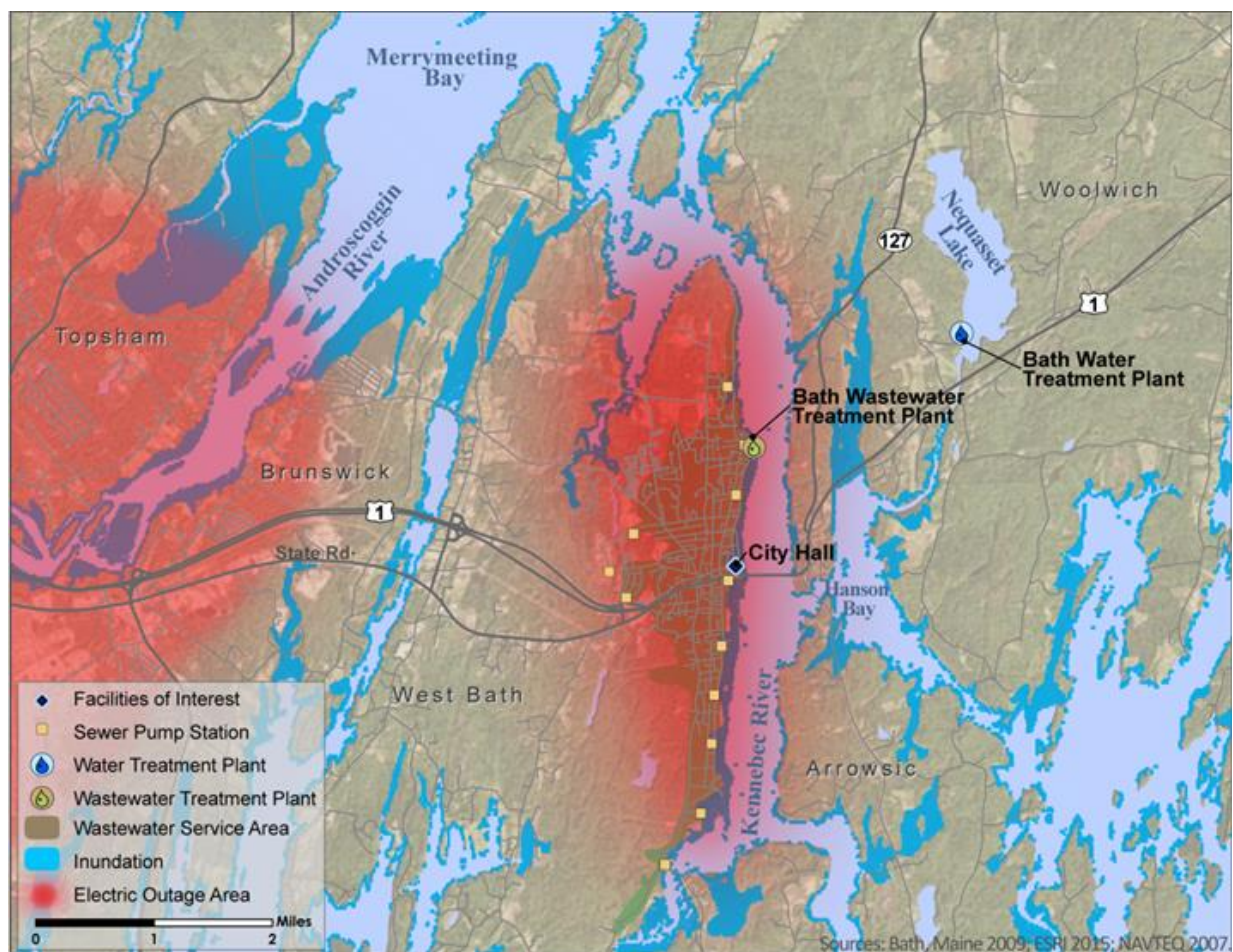


Figure 4 – Possible Effects of the Power Outage Case Study

## 4.2 Florida Fuels RRAP

No significant oil production facilities or refineries exist in Florida, so all petroleum products must be transported into the State. The primary goal of the Florida Fuels RRAP was to provide Florida agencies with actionable analysis to help them improve their understanding of the complex petroleum fuel supply chain serving the State, which would help them identify overall vulnerabilities and thus inform efforts that address Florida's fuel transportation system vulnerabilities. In addition, the project also helped State and local planners identify overall vulnerabilities throughout the petroleum fuel supply chain and develop a realistic strategy designed to mitigate and manage a large-scale failure of petroleum-related port operations.

Figure 5 presents case study results from the Florida Fuels RRAP that illustrate the propagating disruptions between the natural gas and electric power infrastructure systems in Florida modeled with *EPfast* and *NGfast*. In this example, analysts were able to combine two tools used in dependency analyses to model interdependencies between systems (i.e., a “system of systems”).

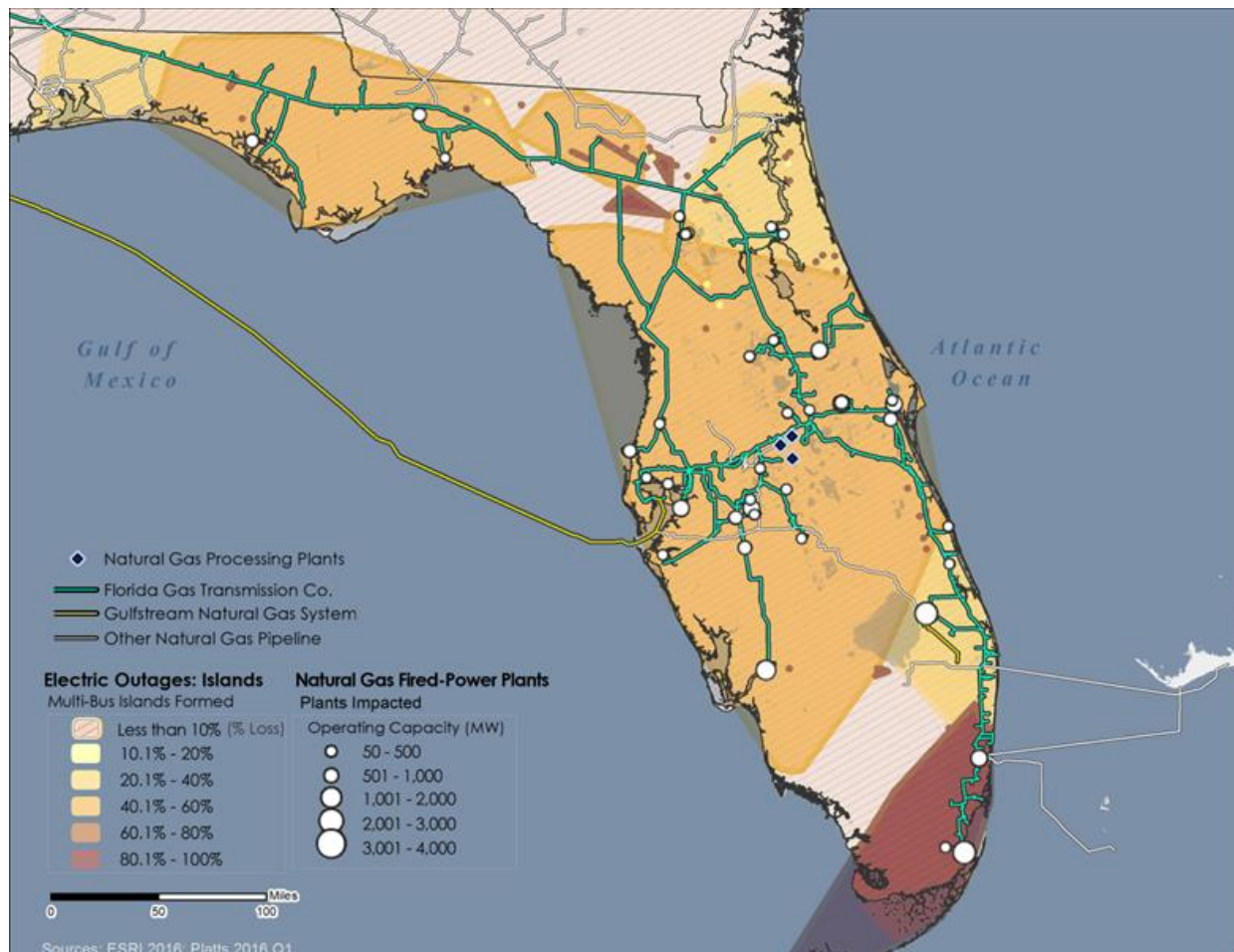


Figure 5 – Example of “System of Systems” Modeling and Failure Analysis (Source: Portante *et al.* 2016)



The scenario postulates the occurrence of a complete break on a major interstate transmission pipeline supplying natural gas to the State, which results in a 100 percent reduction in the flow of gas through the pipeline. The pipeline break also disrupts fuel delivery to a large number of gas-fired power plants in the State.<sup>5</sup> Electric power generation would be affected, leading to statewide potential disruptions with varying load loss intensity ranging from 10 to 100 percent (Portante et al. 2016).

### 4.3 Cajon Pass RRAP

The Cajon Pass is a vital corridor between Southern California and the rest of the Nation. Energy, communications, and transportation infrastructure (i.e., road and rail lines carrying goods to and from the Ports of Los Angeles and Long Beach) cross the Pass. The Cajon Pass RRAP assessed impacts on these essential systems after postulating the occurrence of a major earthquake at the southern San Andreas Fault. As part of this project, DHS conducted detailed analyses of (1) the transportation-related economic impacts anticipated from a Cajon Pass closure, and (2) consequences of earthquake-induced power outages, as well as outcomes of different restoration strategies for Cajon Pass electric assets.

System-level modeling is useful in characterizing both the activities and time needed to restore a critical infrastructure system after degradation. The Cajon Pass RRAP project used the Restore© model, a stand-alone program that runs Monte Carlo simulations using transition diagrams to model infrastructure repair processes. Restore© estimates the restoration time(s) for a selected infrastructure asset or system while accounting for uncertainty (e.g., dependencies on lifeline infrastructure sectors). Based on the identified restoration steps, the model defines the time distribution for completing the system restoration. In the Cajon Pass RRAP, analysts used Restore© to determine reasonable restoration times for earthquake-damaged rail and road infrastructure within the Pass.

Figure 6 shows example output from the Restore© model using a transition diagram that considers transportation and telecommunications dependencies within the steps required to repair a ruptured natural gas pipeline.

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<sup>5</sup> An additional natural gas pipeline is scheduled to be operational by mid-year in 2017, which will mitigate the effects identified during this RRAP.

## Regional Resiliency Assessment Program Dependency Analysis Framework

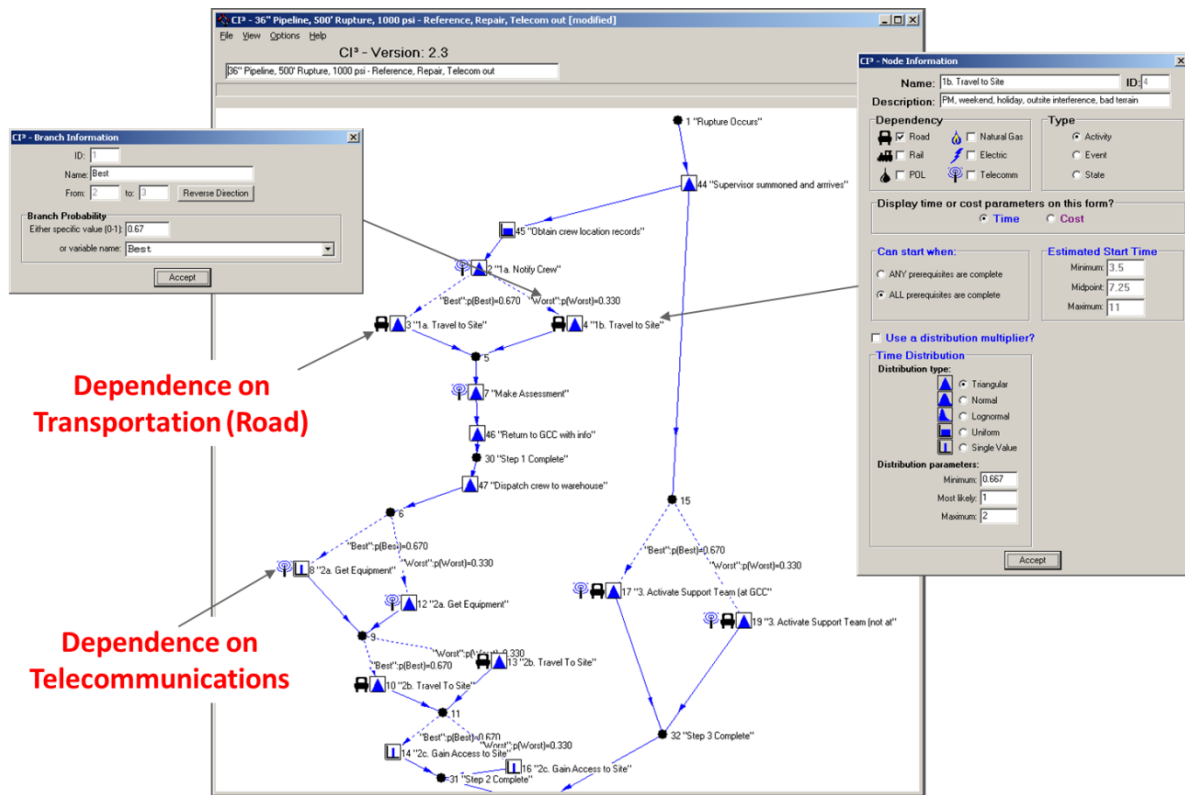


Figure 6 – Repair and Restoration of a Ruptured Natural Gas Pipeline

### 4.4 Port of Charleston RRAP

The Port of Charleston RRAP project assessed the vulnerabilities of port terminals and regional surface transportation networks with a focus on the critical dependencies among assets, systems, and operations that facilitate the port's intermodal capabilities and the region's freight mobility capacities. Operations at all five port terminals depend on services and resources from supporting regional lifeline infrastructure. In order to operate at full capacity, dependencies on electric power, fuels, transportation routes, communications, information technology (IT), water, and wastewater must be satisfied. Degradation of one or a combination of these service and resource supplies would have a detrimental effect on the port operations.

As part of this RRAP, analysts collected dependency data—considered a bottom-up approach or analysis effort—from South Carolina Port Authority terminals (Figure 7).

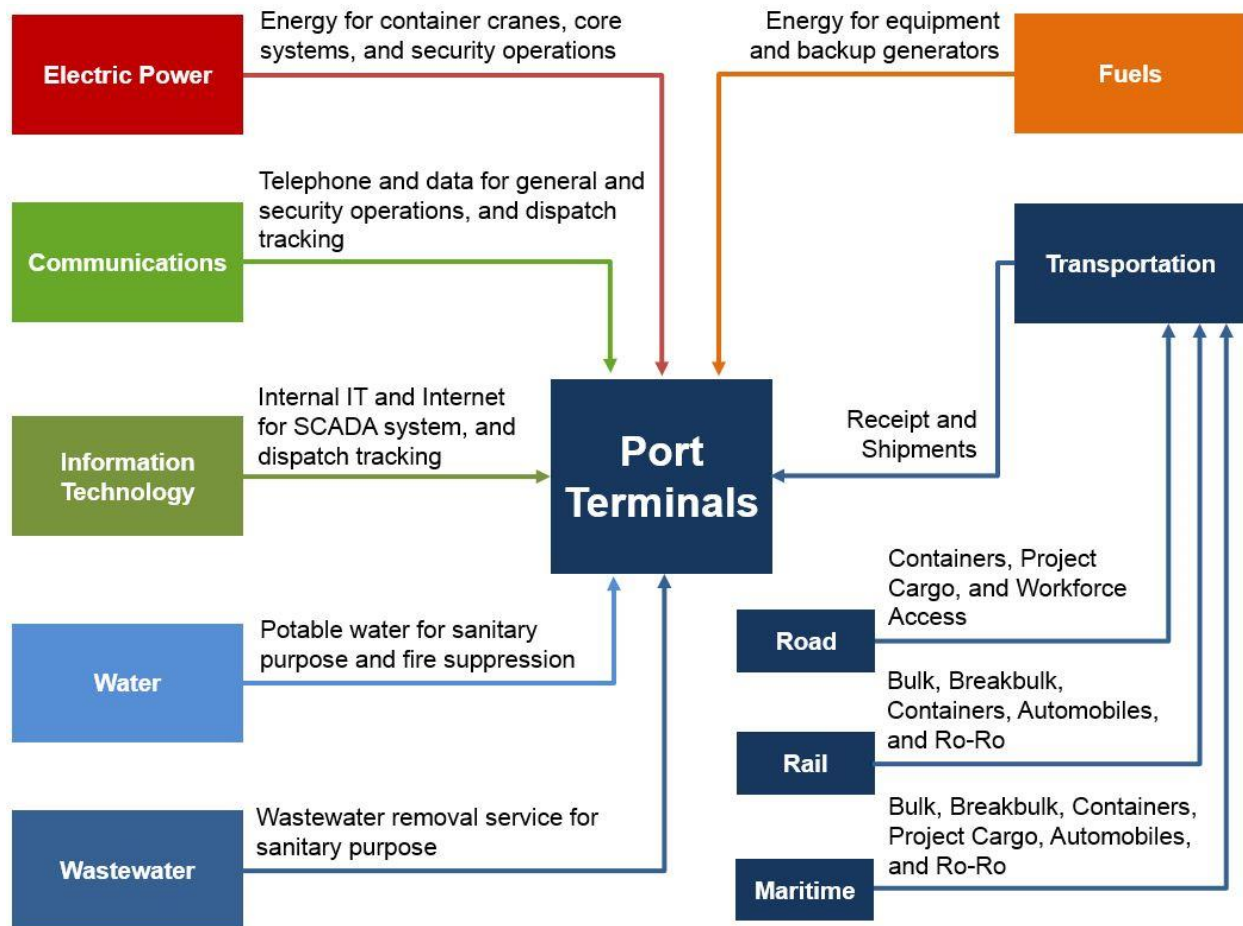
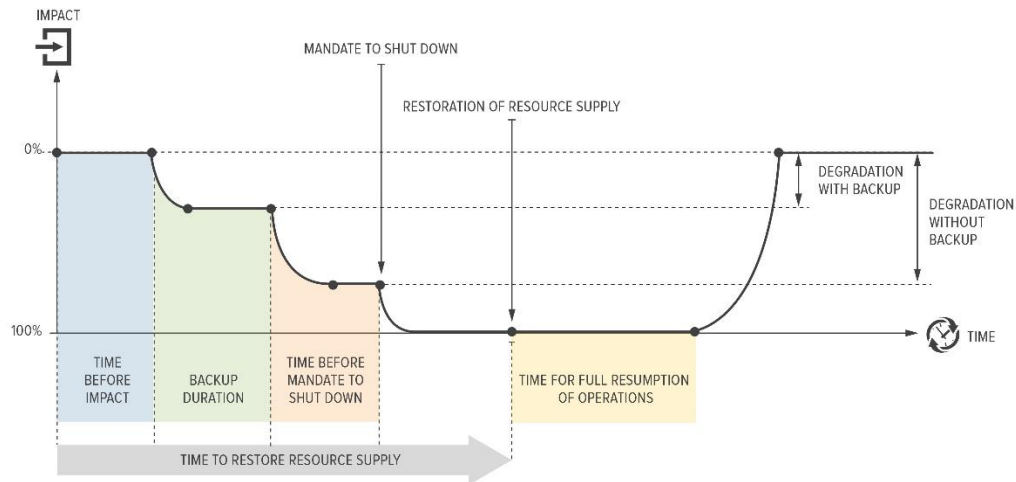


Figure 7 – Overview of Upstream Dependencies for Port Terminals<sup>6</sup>

This information allowed analysts to generate dependency curves for all first-order upstream dependencies at port terminals, showing how the failure of critical infrastructure systems would affect a specific facility over time. Figure 8 presents how facility-level information can be integrated in a dependency curve, which represents the impact of the loss of a given resource over time.

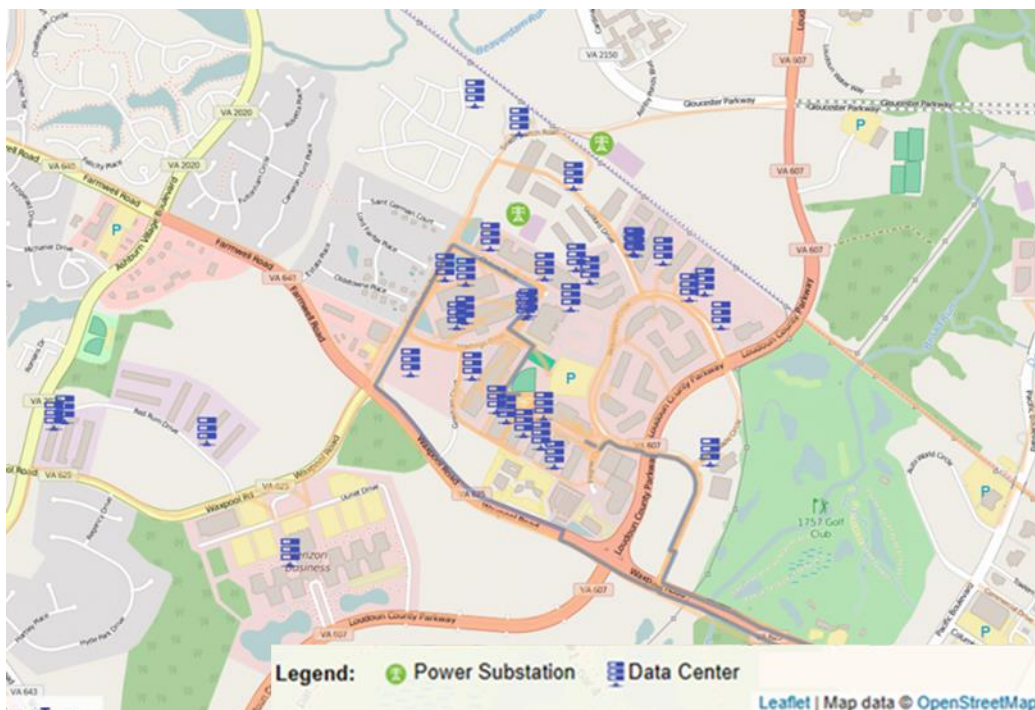
<sup>6</sup> Ro-Ro—Roll On, Roll Off.



**Figure 8 – Example of Facility Dependency Curve (Source: Petit, Wallace, and Phillips 2014)**

#### 4.5 Ashburn RRAP

The Ashburn RRAP focused on the resilience of the Internet backbone infrastructure located in the Ashburn area of Northern Virginia. The cluster of data centers in this region is an important interconnection point for global Internet traffic given the presence of major Interexchange points. With its unique concentration of both fiber and power, on average, 50 to 70 percent of all worldwide Internet traffic flows through the greater Ashburn-area data centers. The infrastructure examined in this project included individual fiber routes and installations; data centers; communications providers; and the power, water, and emergency services sectors that support Internet infrastructure (Figure 9).



**Figure 9 – Cluster of Data Centers in Loudoun County**

Among the outputs created through this RRAP was a dynamic, geographic information system (GIS) product that visualizes infrastructure dependencies both spatially and temporally, allowing analysts to test different scenarios to evaluate the extent of potential consequences generated by potential dysfunction occurring within utility systems.

In the case of Ashburn, transportation infrastructure and private trucking companies are necessary to supply diesel fuel to data center facilities in the event of an extended electric interruption. The tool that the team developed provides an option that shows the outage area generated by the disruption of electric power substations and identifies what data centers would be affected. Predicted outage area is based on an *EPfast* scenario that assumes summer peak-day load conditions that are derived from proprietary electric infrastructure information.

There are more than 20 data centers clustered around the Beaumeade Circle area in Ashburn (Figure 10).



**Figure 10 – Beaumeade Circle Data Center Cluster<sup>7</sup>**

Data centers in the Beaumeade Circle area collectively would require deliveries from three to seven fuel trucks per hour to run at full capacity if they were operating entirely on electric power from their onsite

<sup>7</sup> All data center information in this map was gathered from publicly available sources. Information should not be considered complete. The data are “best-effort accurate” as of fall 2015.

generators. During an electric power outage, other infrastructure assets in the area would also require fuel to operate their backup generators, which would result both in logistical difficulties in delivering the fuel and in supply constraints.

## 5 SUMMARY AND NEXT STEPS

The common understanding and consistent analytic approach for critical infrastructure dependencies and interdependencies outlined here prioritizes the need to tie together top-down and bottom-up approaches in order to produce a comprehensive “system of systems” understanding that can inform PSCD programs, including but not limited to the RRAP. In particular, this approach provides a conceptual foundation for conducting dependency-focused RRAPs, as well as hazard-driven RRAPs that account for the effects of specific natural and human-caused hazards on interdependent infrastructure systems.

Looking ahead, PSCD can advance efforts to institutionalize this framework for analyzing critical infrastructure dependencies and interdependencies by pursuing the following activities of:

- Convening a joint workshop with PSCD headquarters and field personnel, Infrastructure Information Collection Division (IICD), and national laboratory stakeholders to identify near-term opportunities that leverage both the bottom-up Dependency Survey Tool and top-down multisystem modeling and failure analysis capabilities in emerging RRAP projects.
- Updating existing training on dependencies and interdependencies (e.g., one-day dependency training delivered to analysts within the Office of Cyber and Infrastructure Analysis) to reflect this framework and deliver the training to RRAP teams and stakeholders to ensure common understanding of key concepts.
- Defining a common analytical framework for all types of RRAPs—including characterization projects, dependency projects, and hazard-driven projects—that expands on the building blocks of data, analysis, and products used in this approach and provides a shared roadmap for RRAP projects that explore different infrastructure systems across the Nation.



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## APPENDIX A: RRAP PROJECT EXAMPLES

Tables A-1 through A-5 present a list of the models, along with a description of the dependency analysis process and data, used for three Regional Resiliency Assessment Programs (RRAPs): Maine, Florida Fuels, and Ashburn.

Table A-1 – Maine, Florida Fuels, and Ashburn RRAP Objectives and Dependencies Assessments

RRAP	Objective	General Description of Dependencies Assessment
<b>Maine</b>	Coastal lifeline sectors were examined in the context of what impacts they are likely to experience as a result of climate change.	<p>The dependency analysis in the Maine RRAP consisted of two components: a high-level regional analysis, and a focused case study of electrical infrastructure dependencies in the vicinity of Bath, Maine.</p> <p><b>High-Level Regional Analysis:</b> Analysis of energy supply–consumption balance and dependent systems (e.g., natural gas consumption for power generation).</p> <p><b>Focused Bath Case Study:</b> (1) Geospatial analysis of storm-surge inundation of coastal substations (data: EIS,<sup>a</sup> HSIP, ORNL Storm Surge; models: SLOSH); (2) followed by an analysis of potential cascading grid failure and outage area (data: EIA, HSIP; models: <i>EPfast</i>); (3) followed by a geospatial analysis of critical infrastructure falling within the outage areas (data: open source water/wastewater, HSIP; models: ESRI ArcGIS. Products: GIS mapping of outage area and dependent critical infrastructure; analysis of restoration and recovery capabilities of affected infrastructure.</p>
<b>Florida Fuels</b>	Florida’s transportation system was analyzed, as well as the critical infrastructure it supports that is integral to the delivery of petroleum fuels. The resilience of port operations and the SCADA systems that support petroleum fuel deliveries were also analyzed.	<p>The dependency analysis in the Florida Fuels RRAP consisted of two components: a high-level regional analysis of fuel distribution/transportation, and a focused case study of site accessibility and alternate fuel transportation options/needs at Port Canaveral.</p> <p><b>High-Level Regional Analysis:</b> Analysis of fuel terminal service area that implemented a gravity-based retail coverage area model to link likely supply terminals with county-level demand/consumption areas. Scenarios were then introduced to determine how these service areas would shift if a supply terminal were disrupted, and then the roadways into these shifting supply areas were located to identify priority transportation corridors to deliver fuel to affected areas.</p> <p><b>Focused Case Study:</b> (1) Identification of two likely rerouting paths across adjacent NASA and USAF properties in the event that primary/sole access to Port Canaveral were disrupted (highway bridge due to storm impacts); (2) engineering cost estimate to determine investment required to improve roadway infrastructure along two identified alternate routes to accommodate increased fuel truck traffic.</p>
<b>Ashburn</b>	Provide the VDEM and the Virginia Homeland Security Advisor with actionable analysis on the critical dependencies and interdependencies of lifeline infrastructure supporting the operations of the Ashburn-area data cluster.	<p>The dependency analysis in the Ashburn RRAP focused on the analysis of data center dependencies in the region of Ashburn. The study focused on utilities (i.e., electric power, petroleum, water) distribution/transportation, with a specific emphasis on communications and information technology dependencies.</p> <p>The study led to the development of a cascading failures and restoration dependencies visualization tool.</p>
<sup>a</sup> Abbreviations used in this table: EIA—Energy Information Administration; EIS—Environmental Impact Statements; ESRI—Environmental Systems Research Institute; HSIP—Homeland Security Infrastructure Program; GIS—geographic information system; NASA—National Aeronautics and Space Administration; ORNL—Oak Ridge National Laboratory; SCADA—supervisory control and data acquisition; SLOSH—Sea, Lake, and Overland Surges from Hurricanes; USAF—U.S. Air Force; VDEM—Virginia Department of Emergency Management.		

Table A-2 – Energy Sector Models and Data

RRAP	Electric Power	Natural Gas	Petroleum
<b>Maine</b>	<b>Data:</b> Energy Visuals; Platts, EIA <sup>a</sup> <b>Models:</b> <i>EPfast</i> <b>Products:</b> Outage areas; single-line diagrams; substation consumption demand diagrams; power plant peak production diagrams; GIS mapping <b>Stakeholders:</b> Central Maine Power; Maine Governor’s Energy Office	<b>Data:</b> Platts; NPSMS <b>Models:</b> N/A <b>Products:</b> Mapping pipelines, power plants, compressor stations; regional import/export analysis; county- and sector-based consumption analysis <b>Stakeholders:</b> Bangor Gas Company; Maine Natural Gas, LLC; Northern Utilities; Summit Natural Gas of Maine; Trans-Canada/Portland Natural Gas Transmission Systems	<b>Data:</b> Platts; NPSMS; FERC; AAR; EIA <b>Models:</b> N/A <b>Products:</b> Supply/demand balance; terminal capacity diagrams; geospatial mapping <b>Stakeholders:</b> City of Portland; City of South Portland; Greater Portland Council of Governments; Maine Department of Transportation; Maine Emergency Management Agency; Maine Geological Survey; University of Maine Climate Change Institute
<b>Florida Fuels</b>	<b>Data:</b> Energy Visuals; Platts, EIA <b>Models:</b> <i>EPfast</i> <b>Products:</b> Outage areas; single-line diagrams; substation consumption demand diagrams; power plant peak production diagrams; GIS mapping <b>Stakeholders:</b> Duke Energy; FDEM; Florida Power & Light; JEA; TECO	<b>Data:</b> Platts; NPSMS <b>Models:</b> N/A <b>Products:</b> Mapping pipelines, power plants, compressor stations; regional import/export analysis; county- and sector-based consumption analysis <b>Stakeholders:</b> Chesapeake Utilities Corps, Florida Public Utilities; Florida City Gas; Florida Gas Transmission Co.; Florida Power & Light (natural gas power plants); Gulfstream Natural Gas; TECO’s Peoples Gas System	<b>Data:</b> Platts; NPSMS; FERC; AAR; EIA <b>Models:</b> Gravity-based supply/demand market segmentation model <b>Products:</b> GIS mapping products showing fuel terminal service areas, and shifts in service areas due to disruption <b>Stakeholders:</b> FDEM; JAXPORT: Port Canaveral; Port Everglades; Port of Tampa; and numerous facility owners (Marathon, Buckeye, Transmontaigne, Chevron, etc.)
<b>Ashburn</b>	<b>Data:</b> ESRI; Navteq; Platts <b>Models:</b> <i>EPfast</i> , Restore© <b>Products:</b> Outage areas; single-line diagrams; substation consumption demand diagrams; power plant peak production diagrams; GIS mapping; transition diagram; restoration operations and time <b>Stakeholders:</b> Dominion Power	N/A	<b>Data:</b> Platts; ESRI; Navteq <b>Models:</b> N/A <b>Products:</b> Terminal capacity diagrams; geospatial mapping <b>Stakeholders:</b> Colonial; Fannon Petroleum; Mirant Piney Point; Nustar; Plantation

<sup>a</sup> Abbreviations used in this table: AAR—Association of American Railroads; EIA—Energy Information Administration; FDEM—Florida Department of Emergency Management; FERC—Federal Energy Regulatory Commission; GIS—geographic information system; JAXPORT—Jacksonville Port Authority; JEA—Jacksonville Electric Authority; N/A—not applicable; NPSMS—NonPoint Source Management System; TECO—TECO Energy.

Table A-3 – Transportation Models and Data

RRAP	Air	Maritime	Pipeline	Rail	Road
<b>Maine</b>	<b>Data:</b> HSIP <sup>a</sup> Gold, Navteq <b>Models:</b> N/A <b>Products:</b> GIS map products of facilities <b>Stakeholders:</b> Portland Jetport	<b>Data:</b> HSIP Gold, Navteq <b>Models:</b> N/A <b>Products:</b> GIS map products of facilities <b>Stakeholders:</b> Casco Bay Lines; Maine Port Authority	<b>Data:</b> HSIP Gold, Navteq <b>Models:</b> N/A <b>Products:</b> GIS map products of facilities <b>Stakeholders:</b> Trans-Canada/Portland Natural Gas Transmission Systems	<b>Data:</b> HSIP Gold, Navteq <b>Models:</b> N/A <b>Products:</b> GIS map products of facilities <b>Stakeholders:</b> St. Lawrence & Atlantic Railroad	<b>Data:</b> HSIP Gold, Maine DOT Culvert Adaptation Report, Navteq <b>Models:</b> N/A <b>Products:</b> GIS map products of facilities <b>Stakeholders:</b> Maine DOT; Maine Turnpike Authority
<b>Florida Fuels</b>	<b>Data:</b> HSIP Gold, Navteq <b>Models:</b> N/A <b>Products:</b> GIS map products of facilities, fuel supply to Orlando <b>Stakeholders:</b> Orlando International Airport (Greater Orlando Aviation Authority)	<b>Data:</b> HSIP Gold, Navteq <b>Models:</b> GIS map products of facilities; rerouting engineering cost/feasibility study <b>Products:</b> Port accessibility/rerouting study engineering cost estimate <b>Stakeholders:</b> JAXPORT; Port Everglades; Port Tampa Bay; Seaport Canaveral; USCG	<b>Data:</b> Platts; Florida SERT <b>Models:</b> <i>NGfast</i> <b>Products:</b> Mapping pipelines, power plants, compressor stations; regional import/export analysis; county- and sector-based consumption analysis <b>Stakeholders:</b> Florida City Gas; Florida Gas Transmission; Florida Power & Light; Gulfstream Natural Gas; Tampa Pipeline Corp.; TECO's Peoples Gas System;	<b>Data:</b> HSIP, FDOT, ESRI <b>Models:</b> N/A <b>Products:</b> GIS-based maps of facility inundation due to hurricane storm surge-related flooding <b>Stakeholders:</b> CSX; FEC; Norfolk Southern	<b>Data:</b> HSIP Gold; Navteq; FDOT roadway GIS data; FDOT/NBI bridge data; USAF Cape Canaveral Air Force Station; NASA Kennedy Space Center pavement study <b>Models:</b> RS Means civil construction cost data <b>Products:</b> Engineering feasibility/cost study of roadway upgrades <b>Stakeholders:</b> FDOT; Florida DEM; NASA Kennedy Space Center; Port Canaveral; USAF Cape Canaveral Air Force Station
<b>Ashburn</b>	N/A	N/A	<b>Data:</b> Platts; ESRI; Navteq <b>Models:</b> N/A <b>Products:</b> Mapping pipelines <b>Stakeholders:</b> Colonial; Fannon Petroleum; Mirant Piney Point; Nustar; Plantation	N/A	N/A

<sup>a</sup> Abbreviations used in this table: DEM—Department of Emergency Management; DOT—Department of Transportation; ESRI—Environmental Systems Research Institute; FDOT—Florida Department of Transportation; FEC—Florida East Coast Railway; GIS—geographic information system; HSIP—Homeland Security Infrastructure Program; JAXPORT—Jacksonville Port Authority; N/A—not applicable; NASA—National Aeronautics and Space Administration; NBI—National Bridge Inventory; SERT—State Emergency Response Team; TECO—TECO Energy; USAF—U.S. Air Force; USCG—U.S. Coast Guard.

Table A-4 – Water Models and Data

RRAP	Water	Wastewater
<b>Maine</b>	<b>Data:</b> HSIP, <sup>a</sup> Platts, Navteq <b>Models:</b> N/A <b>Products:</b> GIS mapping products - water pumping stations, water treatment facilities <b>Stakeholders:</b> Casco Bay Estuary Project; City of Portland; City of South Portland; NOAA; Portland Water District; Town of Freeport; Town of Saco Water District; USEPA	<b>Data:</b> HSIP, Platts, Navteq <b>Models:</b> N/A <b>Products:</b> GIS mapping products—wastewater treatment facilities <b>Stakeholders:</b> Casco Bay Estuary Project; City of Portland; City of South Portland; NOAA; Portland Water District; Town of Brunswick Sewer District; Town of Freeport; Town of Saco Water District; USEPA
<b>Florida Fuels</b>	<b>Data:</b> HSIP, Florida SERT <b>Models:</b> N/A <b>Products:</b> GIS mapping products—water pumping stations, water treatment facilities <b>Stakeholders:</b> City of Fort Lauderdale (Port Everglades); JEA (Port of Jacksonville/JAXPORT)	<b>Data:</b> HSIP, Florida SERT <b>Models:</b> N/A <b>Products:</b> GIS mapping products—water pumping stations, water treatment facilities <b>Stakeholders:</b> City of Fort Lauderdale (Port Everglades); JEA (Port of Jacksonville/JAXPORT)
<b>Ashburn</b>	<b>Data:</b> HSIP; ESRI; Loudoun Water & County <b>Models:</b> N/A <b>Products:</b> GIS mapping products—Township Water Service; Community System; Loudoun Central Service Area; Industrial Well; Individual Well <b>Stakeholders:</b> Fairfax Water; Loudoun Water	N/A
<sup>a</sup> <b>Abbreviations used in this table:</b> ESRI—Environmental Systems Research Institute; GIS—geographic information system; HSIP—Homeland Security Infrastructure Program; JAXPORT—Jacksonville Port Authority; JEA—Jacksonville Electric Authority; N/A—not applicable; NOAA—National Oceanic and Atmospheric Administration; SERT—State Emergency Response Team; USEPA—U.S. Environmental Protection Agency.		

Table A-5 – Communications and Information Technology Models and Data

RRAP	Water	Wastewater
<b>Maine</b>	<b>Data:</b> HSIP, <sup>a</sup> Platts, Navteq <b>Models:</b> N/A <b>Products:</b> GIS mapping products—cellular tower, microwave service tower, Regional Bell Operating Co., Civer Line, Wirecenter Boundaries <b>Stakeholders:</b> AT&T Wireless; DHS National Coordinating Center for Communications; FEMA; Maine Emergency Management Agency; Maine OIT; State of Maine Office of Geographic Information Systems; Verizon Wireless	<b>Data:</b> HSIP, Platts, Navteq <b>Models:</b> N/A <b>Products:</b> GIS mapping products—cellular tower, microwave service tower, Regional Bell Operating Co., Civer Line, Wirecenter Boundaries <b>Stakeholders:</b> AT&T Wireless; DHS National Coordinating Center for Communications; FEMA; Maine Emergency Management Agency; Maine OIT; State of Maine Office of Geographic Information Systems; Verizon Wireless
<b>Florida Fuels</b>	<b>Data:</b> Telecordia; FCC; HSIP <b>Models:</b> N/A <b>Products:</b> GIS mapping products—cellular tower, microwave service tower, Wirecenter Boundaries <b>Stakeholders:</b> AT&T (BellSouth Telecommunications, Inc.); FDEM	<b>Data:</b> Telecordia; FCC; HSIP <b>Models:</b> N/A <b>Products:</b> GIS mapping products - cellular tower, microwave service tower, Wirecenter Boundaries <b>Stakeholders:</b> AT&T (BellSouth Telecommunications, Inc.); FDEM
<b>Ashburn</b>	<b>Data:</b> Telecordia; FCC; HSIP, NCCIC <b>Models:</b> NCCIC Modeling Analysis: Wireline, Wireless, Emergency Services <b>Products:</b> GIS mapping products—cellular tower, microwave service tower, Wirecenter Boundaries Regional Bell Operating Co., competitive local exchange carrier, personal communication service, telecom hotels location and tenants <b>Stakeholders:</b> AT&T, Verizon, datacenters	<b>Data:</b> Telegeography; Loudoun County Office of Economic Development; HSIP <b>Models:</b> N/A <b>Products:</b> GIS mapping products—network map; fiber routes; datacenters complex; <b>Stakeholders:</b> Accenture; Airbnb; Akamai; Alcatel Lucent; Allied Fiber; Amazon; Architect of the Capitol; Assa Abloy; AT&T; Centers for Disease Control and Prevention; CenturyLink, Code.org; Comcast; COX Communications; Dominion Power; Dow Jones; DuPont Fabros Technology; Equinix, Evoswitch; Excel Courier; Expedia; Fannon Petroleum; Google; The Guardian; HTC; IAN LLC; InfraGard; NASA; National Emergency Numbers Association; Netflix; Neustar Networks; New York City Department of Transportation; Newsweek; Nokia; Open IX; Pfizer; Primary Integrations; Raging Wire; SAP; Schneider Electric; Siemens; Sprint; State of Arizona; SummitIG; Swift; Uptime Institute; U.S. Food and Drug Administration Verisign; Verizon; Visa;
<sup>a</sup> Abbreviations used in this table: DHS—U.S. Department of Homeland Security; FCC—Federal Communications Commission; FDEM—Florida Department of Emergency Management; FEMA—Federal Emergency Management Agency; GIS—geographic information system; HSIP—Homeland Security Infrastructure Program; HTC—High Tech Computer Corporation; IAN—Instant Access Networks; N/A—not applicable; NASA—National Aeronautics and Space Administration; NCCIC—National Cybersecurity and Communications Integration Center; OIT—Office of Information Technology; SAP—Systems, Applications, and Products.		





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